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DREDGED MATERIAL RESEARCH

U. S. ARMY CORPS OF ENGINEERS
INFORMATION EXCHANGE BULLETIN

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12 p.

NOTES • NEWS • REVIEWS, etc

Vol D-77-6.

What equipment can perform survey tasks or productive work in a disposal area where the dredged material slurry may have reached the consistency of warm axle grease or may be "too thin to walk on and too thick to swim in"? A catalogue of equipment for operation in containment areas, prepared as part of the Dredged Material Research Program (DMRP), is described in the following article.

DAEWES Vicksburg Miss 038100

INVENTORY OF LOW-GROUND-PRESSURE CONSTRUCTION EQUIPMENT FOR OPERATION AND MAINTENANCE OF DISPOSAL AREAS

A recent dramatic increase in the amount of land used for confined dredged material disposal areas has caused increased attention to be focused on the design, construction, and management of these containment areas. Task 2C (Containment Area Operations) is part of the Disposal Operations Project of the DMRP, which among other considerations includes research into various ways of improving the efficiency and acceptability of facilities for confining dredged material on land.

Work in and around containment areas usually requires special equipment because of the soft dredged material and poor foundation conditions usually associated with such areas. Consequently, investigations for improved facility design, construction, and management would be incomplete without an assessment of vehicles or equipment that can perform productive work in containment areas. The assessment is being accomplished by the Waterways Experiment Station's Mobility and Environmental Systems Laboratory (MESL).

Three studies are under way to provide guidance for the selection of equipment and use of the equipment in and around containment areas: an equipment inventory and preliminary performance predictions; problem definition and site characterization; and field verification of equipment. The following article describes the equipment inventory and preliminary performance predictions made under DMRP Work Unit 2C09A.

FIELD STUDY

A limited field data-collection program was conducted to determine the magnitude of the stress level that the environment of dredged material containment areas may produce on ground-crawling equipment operating in these areas. Five dredged material containment areas were selected that had a high probability of offering a range in operational difficulty.

Criteria for selection were primary type and consistency of the dredged material. Five disposal areas were chosen for study: Blakeley Island, Pinto Island, and McDuffie Island in the Mobile District; Barnwell Island in the Savannah District; and Craney Island in the Norfolk District. Conditions at each site were characterized to describe the area for mobility purposes using the cone index/rating cone index system, which has been used for many years in soil trafficability for military purposes. Table 1 is a summary of the site descriptions of the operational environments from a trafficability standpoint.

The soils data revealed that the operational environment of confined dredged material disposal areas can be highly variable within a given site in terms of material, profile strength, presence of surface and subsurface water, and vegetal cover. These factors combine to present a very harsh operational environment for vehicles or equipment.

Table 1
OPERATIONAL ENVIRONMENTS FOR SELECTED DISPOSAL AREAS

Location of Disposal Area	Coverage, %*		Coarse-Grained Soil				Fine-Grained Soil			
	Surface Water	Vegetation	Area %*	Types	Average CI, Range 0-6 in.	Average CI, Range 6-12 in.	Area %*	Types	Average CI, Range 0-6 in.	Average CI, Range 6-12 in.
Mobile District:										
Blakeley Island	40	0	15	SP	8-32	4-100+	85	MH,CH	8-24	2-18
Pinto Island	2	2	25	SP	63**	78**	75	CH	5-14	2-5
McDuffie Island	2	98	0	--	--	--	100	CL,CH	5-40	2-8
Savannah District:										
Barnwell Island	5	40	20	SP	73-85	98-100+	80	MH,CH	4-34	4-29
Norfolk District:										
Craney Island	40	2	20	SP	72-87	96-100+	80	CH,ML	1-55	1-60

* Estimated.
** Represents only one sample site.

VEHICLE CATALOG

A literature search, personal contact with manufacturers, and the expected operational environments established the limits of the vehicle inventory. A vehicle catalog was compiled that included commercially available vehicles and some standard and experimental military vehicles that have the potential for operating in dredged material environments.

Sixty vehicles were evaluated analytically to determine their capabilities for operating in and around dredged material disposal areas. The results represent the state-of-the-art vehicles that can operate in soft soils.

The vehicles were divided into six payload classes that indirectly reflect the size of the job that the vehicle or equipment may be expected to perform. Vehicle performance was expressed in terms of GO-NO GO and traction capability on five selected soil strengths that cover the range of soil strengths that are believed to be representative of many operational environments.

A comparison of the computed soil strength requirements for the vehicles operating in fine-grained soils with measured soil strength data indicated that commercially available vehicles in all six payload classes can operate in all except the lowest soil strength units established. Only the Riverine Utility Craft (RUC) was predicted to operate in all the strength units.

Pertinent data are presented in the report in catalogue form: photos or drawings, manufacturer, general vehicle data (including performance data), mechanical data with dimensions or description of major components, and miscellaneous data such as information on costs and primary uses.

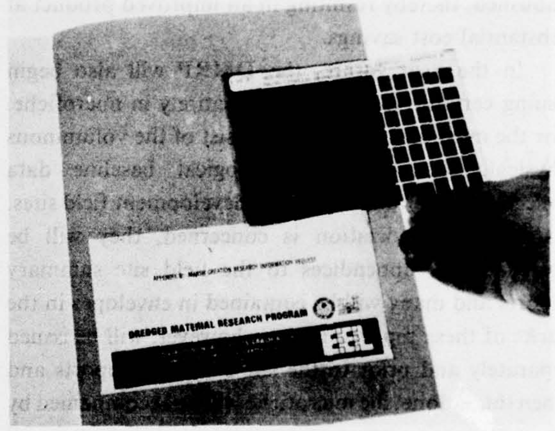
Caution should be exercised in using the information in the report to select vehicles for operation in borderline situations. The performance of the vehicles was predicted analytically, and the vehicles were not field evaluated in dredged material containment areas. The second phase of the vehicle performance study is now under way to evaluate the performance of various vehicles and to identify in more detail the operational environment and functions under which they must perform.

The report, entitled "Low-Ground-Pressure Construction Equipment for Use in Dredged Material Containment Area Operation and Maintenance—Equipment Inventory," was written by Charles E. Green and Adam A. Rula, MESL, as part of the Disposal Operations Project of the DMRP (Charles C. Calhoun, Jr., Manager). Manager of Task 2C was Mr. Newton C. Baker. The report is Technical Report D-77-1 and is available on request.

An addition to DMRP data/results reporting.....

PUBLICATIONS IN MICROFICHE FORM

Those in the Bulletin's audience who have received recent DMRP contract and technical reports or who have noted carefully the citations for new reports in the Bulletin are aware of a "new look" in reports format. The innovation referred to is the use of microfiche* for certain appendices to the reports. As shown in the figure, the microfiche are contained in an appropriately identified envelope located inside the back cover of the report.



The use of microfiche in lieu of publication in printed form for these data has been precipitated by two factors. First and paramount of these is cost. Since the DMRP was initiated more than 4 years ago, the cost of a typical report has at least doubled. In comparison, to issue data in microfiche costs perhaps 10 percent of the amount that would be needed to print the same information in hard copy. The second factor is less tangible and relates to reader acceptability and use. Simply stated, psychologically a 50-page report is more apt to be read by more people than a 500-page report, regardless of content.

* A card-sized (100 x 150 mm) sheet of microfilm containing up to 98 images (pages of original) that can be used in a wide range of commercially available viewers and viewer/printers.

All DMRP reports are being structured and written in a manner to be useable to a wide audience and to be limited to the extent possible to discussion of procedures, findings, interpretations, summarization, and conclusions. However, to be complete and meet professional, legal, and other obligations, they must contain as much raw data (observations, measurements, analytical results, etc.) as possible, and the remaining data must be available in some useable form by any who may have need for them.

Considering all alternatives from full publication to a few file copies and combinations of these, the DMRP staff concluded much information is ideally suited to publication *in full* in microfiche. One such category of data is the detailed, tabulated, backup information that is needed by and used by a very small percentage of any audience—information that would normally be included in appendices. It is expected that a large percentage of this type of data will be in microfiche in the large number of DMRP reports remaining to be published, thereby resulting in an improved product at substantial cost savings.

In the near future, the DMRP will also begin issuing certain types of reports entirely in microfiche. For the most part, these will consist of the voluminous physical, chemical, and biological baseline data collected at the various habitat development field sites. As far as organization is concerned, they will be designated as appendices to the field site summary reports and many will be contained in envelopes in the backs of these reports. Others, however, will be issued separately and prior to the site summary reports and when this is done, the microfiche will be accompanied by an explanatory letter of transmittal, a listing of all reports and appendices in the series for the site, and a printed abstract and accompanying bibliographic data (the DD Form 1473 that appears in all reports).

It is recognized that microfiche are not as convenient for use as printed hard copy; however, they are in such common use today that viewers and machines capable of making prints are normally available in libraries and many offices. The DMRP staff hopes the inconvenience will be accepted in the spirit that is in making a much larger volume of data available to a wider audience at an appreciable savings in public funds.

* * * * *

DMRP PUBLICATIONS—THE VIEW DOWN THE ROAD

With completion of the DMRP less than a year away (March 1978), it should surprise no one that the DMRP management staff is preoccupied with the need to effectively summarize, report, and distribute research results. Prompted in part by the contract study by Teknekron, Inc., of information dissemination and technology transfer performance and requirements, the DMRP staff has taken to the road over the last 10 months to conduct briefings and workshops on a monthly schedule in Corps Division areas (see DMRP Bulletin D-77-4, dated Mar 1977). However, despite the need for and value of these personal contacts with a wide audience of information users, they do not and cannot replace formal reports as the fundamental mode of information dissemination.

As of the 1st of April, the DMRP had published over 50 reports, 36 of which represent the final results of work units or individual studies. The distribution of these by DMRP project and task is shown in the accompanying table. This table also shows that the vast majority of work unit reports (designated either contract or technical reports) are yet to be published (99 scheduled) and only in one task has even half of all reports been issued to date. These work unit reports, all of which will be written, reviewed, and in publication by March 1978, will constitute the basic DMRP library of information needed by the technical specialists, design engineers, or others who require specific study details.

In the same category as far as detail and usefulness are concerned will be an additional planned 13 field site summary reports. These will both present in detail in appendix form the data and results obtained under specific contracts, and interpretations, evaluations, and conclusions of all data in main report form for each of the DMRP aquatic and terrestrial disposal and habitat development field test and demonstration sites. All of these reports are in some stage of preparation and the completion schedule is similar to that for the topical reports. The reader is alerted to the fact that in order to minimize the expected crushing publication workload near the end of the DMRP, certain appendices to site reports may be published and distributed out of sequence and before the main site report in some cases.

The DMRP staff has long been cognizant that a library consisting of a total of 148 topical and site

DREDGED MATERIAL RESEARCH PROGRAM—REPORTS PUBLICATION OUTLOOK

Project/Task	Objective	No. Reports Published	Reports Scheduled: Topical*	Reports Scheduled: Field Site**	Planned Synthesis Reports (Titles)
Environmental Impacts and Criteria Development Project					
1A Aquatic Disposal Field Investigations	Determine the magnitude and extent of effects of disposal sites on organisms and the quality of surrounding water, and the rate, diversity, and extent such sites are recolonized by benthic flora and fauna.	2	2	5	Aquatic Dredged Material Disposal Impacts
1B Movements of Dredged Material	Develop techniques for determining the spatial and temporal distribution of dredged material discharged into various hydrologic regimes.	3	5	--	Fate of Dredged Material Deposits; Mathematical Models of Predicting Fate of Aquatic Disposed Dredged Material
1C Effects of Dredging and Disposal on Water Quality	Determine on a regional basis the short- and long-term effects on water quality due to dredging and discharging bottom sediment containing pollutants.	3	1	--	Water-Quality Impacts of Aquatic Dredged Material Disposal (Lab Investigations)
1D Effects of Dredging and Disposal on Aquatic Organisms	Determine on a regional basis the direct and indirect effects on aquatic organisms due to dredging and disposal operations.	2	9		Aquatic Organism Impacts of Dredged Material Disposal (Lab Investigations)
1E Pollution Status of Dredged Material	Develop techniques for determining the pollutional properties of various dredged material types on a regional basis.	4	6	--	Evaluative Summary of Regulatory Criteria for Public Laws 92-500 and 92-532
2D Confined Disposal Area Effluent and Leachate Control	To characterize the effluent and leachate from confined disposal facilities, determine the magnitude and extent of contamination of surrounding areas, and evaluate methods of control.	--	4	--	Pollutional Status of Upland Dredged Material Containment Areas
Habitat Development Project					
2A Effects of Marsh and Terrestrial Disposal	Identification, evaluation, and monitoring of specific short-term and more general long-term effects of confined and unconfined disposal of dredged material on uplands, marsh, and wetland habitats.	1	4		Assessment of the Impacts of Marsh and Terrestrial Disposal of Dredged Material
4A Marsh Development	Development, testing, and evaluation of the environmental, economic, and engineering feasibility of using dredged material as a substrate for marsh development.	4	15	5	Marsh Plant Productivity on Dredged Material and Natural Habitats; Marsh Plant Establishment on Dredged Material; Engineering Considerations and Cost Effectiveness of Habitat Development on Dredged Material
4B Terrestrial Habitat Development	Development and application of habitat management methodologies to upland disposal areas for purposes of planned habitat creation, reclamation, and mitigation.	--	4	2	Upland Plant Establishment on Dredged Material
4E Aquatic Habitat Development	Evaluation and testing of the environmental, economic, and engineering feasibility of using dredged material as a substrate for aquatic habitat development.	--	2	--	
4F Island Habitat Development	Investigation, evaluation, and testing of methodologies for habitat creation and management on dredged material islands.	--	7		Dredged Material Island Establishment and Disposal Methodology
Disposal Operations Project					
2C Containment Area Operations	Development of new or improved methods for the operation and management of confined disposal areas and associated facilities.	7	8	--	Assessment of Low-Ground-Pressure Equipment in Dredged Material Containment Area Operations and Maintenance; Confined Dredged Material Disposal Area Design, Operation, and Management
5A Dredged Material Densification	Development and testing of promising techniques for dewatering or densifying dredged material using mechanical, biological, and/or chemical techniques prior to, during, and after placement in containment areas.	2	5	1	Guidelines for Dewatering/Densifying Confined Dredged Material
5C Disposal Area Reuse	Investigation of dredged material improvement and rehandling procedures aimed at permitting the removal of material from containment areas for landfill or other uses elsewhere.	3	6		Dredged Material Disposal Area Reuse Management
6B Treatment of Contaminated Dredged Material	Evaluation of physical, chemical, and/or biological methods for the removal and recycling of dredged material constituents.	1	5	--	Treatment of Contaminated Dredged Material
6C Turbidity Prediction and Control	Investigation of the problem of turbidity and development of a predictive capability as well as physical and chemical control methods for employment in both dredging and disposal operations.	1	6	--	Prediction and Control of Dredged Material Dispersion Around Dredging and Disposal Operations
Productive Uses Project					
3B Upland Disposal Concepts Development	Evaluation of new disposal possibilities such as using abandoned pits and mines and investigation of systems involving long-distance transport to large inland disposal facilities.	1	2		Guidelines for Productive Land Use of Dredged Material Containment Areas
4D Products Development	Investigation of technical and economic aspects of the manufacture of marketable products.	1	1		
4C Land Improvement Concepts	Evaluation of the use of dredged material for the development, enhancement, or restoration of land for agriculture and other uses.	--	3		Guidelines for Land Improvement Concepts in Inland Disposal of Dredged Material
5D Disposal Area Land-Use Concepts	Assessment of the technical and economic aspects of the development of disposal areas as landfill sites and the development of recreation-oriented and other public or private land-use concepts.	1	4		

* Final contract or technical reports on specific work units.
** Summaries of all studies, with interpretations and conclusions, at major field investigation demonstration sites.

reports, while impressive in size, will not suffice. At least two other elements are essential. The first is a series of concise documents to summarize and present in less tedious and technical manner and terminology the gist of research results with regard to the main objectives of the DMRP. Designated synthesis reports, the 21 documents of this nature will be manuals or manuallike in content and will be issued within the Corps as formal directives. Indicated by title in the accompanying table, the synthesis reports are scheduled to be completed and published and distributed within the Corps and to a wide non-Corps audience by not later than September 1978.

The second essential element is an index and retrieval system for both the topical and site summary reports as well as the synthesis reports. Preparation of such an access or link to the DMRP library will require a substantial effort: a request for proposals is now being advertised as an initial step toward selecting a contractor for this. It is expected work on the system will begin this summer and will be completed by September 1978.

In addition to these formal publications, others of recognized value will continue. This bulletin serves a need for the timely and inexpensive dissemination of research highlights to a wide audience and will continue to be published until completion of the DMRP. The 4th Annual Report of the DMRP, although behind schedule, will be published in the near future. Various special purpose documents for limited segments of the audience are also included on the total list of anticipated publications.

RECENT AND PLANNED MARSH ESTABLISHMENT WORK THROUGHOUT THE CONTIGUOUS U. S.—A SURVEY AND BASIC GUIDELINES

A survey conducted by Environmental Concern, Inc. (DMRP Work Unit 4A25), indicated considerable research regarding marsh development has been conducted by elements of the Corps of Engineers, Federal and State agencies, and several universities and private firms. The purpose of the survey was to identify those marsh development studies not being conducted by the DMRP and to categorize the projects on the basis of location, size, marsh plant species composition, status, and results. Based on current information, guidelines and recommendations were developed for site preparation, marsh establishment, and site management and maintenance.

SURVEY

The information was obtained by identifying those investigators recently involved in marsh creation in the United States and then interviewing them in person or by telephone or letter. One hundred and five separate projects were identified. The contractor, Dr. E. W. Garbisch, Jr., compiled the results and prepared a tabular and narrative synthesis of the survey.

Of the 105 completed or continuing projects, nine were reported to be totally unsuccessful due to vandalism, goose depredation, wave exposure too severe for seeding, or site surface elevations too low for seeding. Variation encountered in the total number of projects included 18 that existed in freshwater or nearly freshwater locations, 68 that existed on the East Coast, 17 on the Gulf Coast, 8 on the West Coast, and 12 inland. Fifty-nine were purely experimental as opposed to applied or partly so.

GUIDELINES

Many of the data used in developing the guidelines were derived from observations and experience of the contractor and are not necessarily the result of planned experimental tests. Examples of subjects that are not completely understood and for which guidelines are necessarily preliminary include the need for fertilization and the relative desirability of seeding versus sprigging. Consequently, the application of the findings must be tempered with judgement based on local experience or conditions.

Site Preparation

The report indicates that the two most important factors in site preparation are slope and surface elevation. If either or both are not properly constructed, marsh establishment will be jeopardized. Within the tidal zone, surface slopes should be developed such that they exhibit reasonable stabilities in the absence of vegetative cover. Surface elevations must be carefully considered in the design and planning of a project and tied in with the various zones of marsh types existing in the region. Surface elevations are most improtant and their acceptable tolerances most stringent in areas

subject to tidal amplitudes of 0.6 m or less. Preliminary data indicate that design depending on long-term consolidation of fine sediment types is not considered practical in achieving final surface elevations within acceptable tolerances.

Marsh Establishment

All aspects of marsh establishment must be an integral part of the design and planning of the total project. Close coordination between the site preparation and the marsh establishment stages of a project in terms of time of year is considered important; however, the use of nursery plant stock may alleviate the consequence of unacceptable marsh establishment because of unavoidable delays in the site preparation. Selection of the plant species to be used at the site must be governed by (1) the plant species known to exist within given elevational zones in natural marshes in the region, (2) the objectives of the project, and (3) the relative growth rates and sediment stabilizing capabilities of the candidate plants.

Dr. Garbisch considers properly developed nursery stock superior to all other types for sites or sections of sites subjected to high wave and debris deposition stresses and for summer, fall, and winter plantings. He considers marsh establishment by seeding feasible only in the spring, in sheltered or confined areas, and at elevations above mean tidal level (MTL) (preferably the upper 20% of the mean tidal range). A rule of thumb is that increasing the maturity of nursery transplant materials upon decreasing the elevations in the tidal zone will lead to the greatest survival of transplants and the best overall plant establishment. Although fertilization may be used for all marsh establishment work in sand sediments, the need for such fertilizations in other sediment types (silt or clay) is not readily determined.

Dr. Garbisch believes that the three principal maintenance and management requirements for marsh establishment determined by the study are (1) removal of debris and litter depositions, (2) protection against waterfowl depredation, and (3) fertilization. During the growing season, particularly for late spring and summer plants, algae, submerged aquatic plants, free-floating aquatic plants, and/or sundry debris that have been washed and deposited throughout the developing marsh, may have to be periodically removed. Otherwise, the affected plants may be seriously impaired.

Depending upon the prevailing populations of geese, and to a lesser extent other wildlife, marsh establishment sites may have to be protected by enclosures or other effective devices. Areas of marsh establishment sites subject to extended periods of high wave stress may require annual maintenance fertilization to prevent the marsh from succumbing to the stress.

The study was conducted as part of DMRP Task 4A: Marsh Development, Habitat Development Project, Dr. Hanley K. Smith, Manager. The report was published as Contract Report D-77-3 and is now available.

ESTABLISHMENT AND GROWTH OF SELECTED MARSH PLANTS

INTRODUCTION

Greenhouse investigations have been conducted as part of the DMRP to elucidate the primary edaphic factors that affect the establishment and growth of selected marsh plants from different propagules on dredged sediments. These greenhouse investigations are part of Task 4A, Marsh Development, HDP, Dr. Hanley K. Smith, Manager. The HDP has been investigating the possibility of using dredged sediments to create marshes. Because of the stabilizing influence of vegetation on newly deposited dredged sediments and the importance of vegetation as a trophic substrate, emphasis has been placed on methods of establishing plants on dredged sediments. Accordingly, the use of controlled experiments to assess plant-sediment interactions was considered an essential direction of investigation.

Since field investigations of marsh plant-sediment interactions may be adversely affected by uncontrolled climatic, biotic, and hydrologic influences that obscure causal relationships between sediment factors and plant growth, studies to better define these causal relationships were conducted by simulating marsh conditions in a greenhouse. The greenhouse studies were designed to complement ongoing field research.

Representative plant species from freshwater and coastal marsh habitats were selected on the basis of their widespread occurrence or suitability to a particular locale. Coastal marsh species were subdivided on the

basis of their occurrence within different zones in natural marshes. For the purpose of this study, those species more commonly occurring on the seaward edge of a marsh were distinguished as salt marsh plants. Similarly, those species more commonly occurring at higher elevations within a marsh or in areas of lesser salinity were distinguished as brackish marsh plants. These distinctions were made with full knowledge of common overlap in zones of occurrence.

Dredged sediments used in the investigation were obtained from selected freshwater and estuarine locations. The sediments were classified as sand, silty clay, and clay on the basis of particle-size distribution.

Environment/Sediment Type	Source
Freshwater:	
Sand	Intracoastal Waterway between Destin and Panama City, Fla.
Silty clay	Maumee River, Toledo, Ohio
Clay	Drainage canal, Tallulah, La.
Estuarine:	
Sand	Intracoastal Waterway between Destin and Panama City, Fla.
Silty clay	St. John's River, Jacksonville, Fla.
Clay	Savannah River, Savannah, Ga.

Nutrient content of the sediments showed the following pattern: nutrient content of sand < clay < silty clay. Among the estuarine sediments, the free-water salinity of clay and silty clay was 17.8 and 31.8 ppt, respectively. The salinity of the estuarine sand, which was free draining, remained in dynamic equilibrium with the salinities of the tidal waters, which were maintained at 12.0 and 24.0 ppt in brackish and salt marsh simulations, respectively.

All sediments were placed in fiberglass tanks and planted with different propagules of eight plant species representative of freshwater, brackish, and salt marshes (Table 1). Propagules were uniformly distributed across different sediments and subjected to daily inundation that simulated tidal inundation (Figure 1).Growth of each propagule of each species was independently evaluated with respect to characteristics of the different dredged sediments upon which it was established. Growth of each species was evaluated on the basis of total biomass and numbers of stems determined at the end of the investigation.

RESULTS

During the same period of growth, transplants with portions of the aboveground stems left attached (sprigs) produced plant populations having greater biomass and greater numbers of stems than did other vegetative propagules or seed. Rhizomes, rootstocks, and tubers

Table 1

INITIAL BIOMASS AND AREAL DENSITY OF PROPAGULES

Experiment	Plant Species	Propagule	Biomass* Mean g m^{-2} (dry wt)	CV	Areal Density**
Freshwater marsh	*Scirpus validus*	Transplant	133.3	5.5	18
		Rhizome	53.0	3.0	18
	Cyperus esculentus	Transplant	11.5	6.9	36
		Tuber	18.5	5.5	72
Brackish marsh	*Distichlis spicata*	Transplant	134.3	5.0	18
		Seed	–	–	250
	Spartina patens	Transplant	182.9	2.5	18
		Seed			250
	Triglochin maritima	Transplant	119.1	7.0	18
		Rootstock	52.3	4.8	18
	Scirpus robustus	Transplant	168.9	8.0	18
		Rhizome	123.6	4.7	18
Salt marsh	*Spartina alterniflora*	Transplant	332.1	2.6	18
		Seed			250
	Spartina foliosa	Transplant	139.8	2.2	18
		Seed			250

* Means are based on six replications. The coefficient of variability (CV) = the standard deviation ÷ the mean × 100. Dash indicates that no determination of seed mass was made.

** Areal density equals the number of propagules per plot.

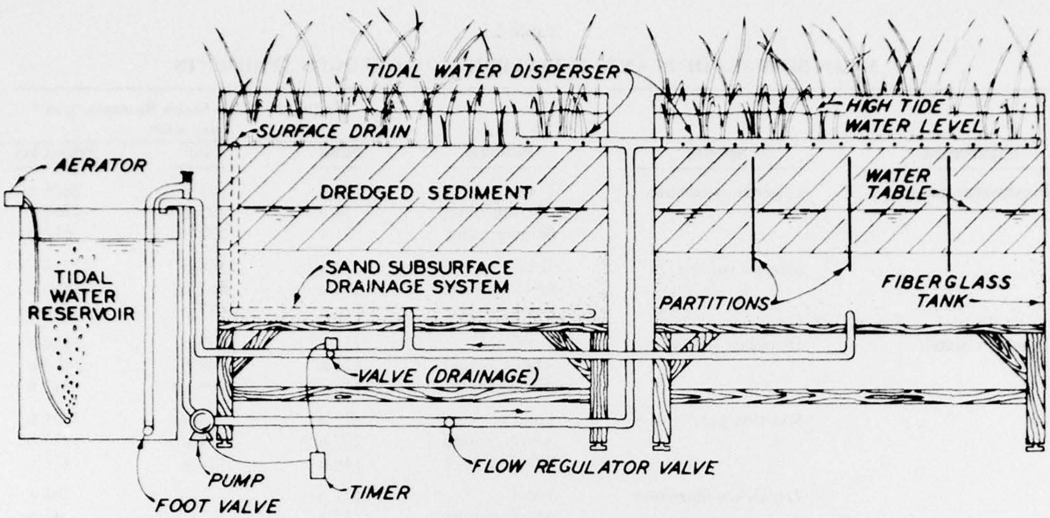


Figure 1. Design of tidal simulation system

responded similarly, but to a lesser extent, than transplants of the same species. In all experiments, seeds were not firmly held by the unconsolidated fine-grained sediments; consequently, losses during tidal inundation were high. Poor growth of seedlings on coarse sediments was attributed to low nutrient concentrations.

Growth of the freshwater species, *Cyperus esculentus* and *Scirpus validus*, followed the pattern: growth on sand < clay < silty clay. Although substantial plant growth on clay was limited by nitrogen, growth on sand was apparently limited by the availability of nitrogen and/or phosphorus.

Among brackish and salt marsh species, only *Spartina alterniflora, S. foliosa, S. patens,* and *Distichlis spicata* were successfully established on all estuarine sediments. *Triglochin maritima* and *Scirpus robustus* could not be established on silty clay and failed to attain appreciable biomass on sand or clay sediments (Table 2). Plant growth on the estuarine sediments generally followed the pattern: growth on sand ≤ silty clay < clay. While growth of all species on sand was apparently limited by the availability of nitrogen and/or phosphorus, the large differences in growth between silty clay and clay could not be attributed to nutrients. The high free-water salinity of silty clay was considered responsible for the reduced growth of plants on this sediment.

During the investigation, an increase in the free-water salinity of the fine-grained estuarine sediments was observed. This salinity increase could not be related to an evaporative concentration of salts, since changes in moisture content during the experiment were negligible. Rather, the increased salinity of these sediments was attributed to salt accumulation in the root zones of salt-excluding marsh plant species used in the investigation. Fine-grained dredged sediments typically have low permeabilities and leaching of accumulated salts did not occur.

CONCLUSIONS AND RECOMMENDATIONS

Distichlis spicata was the only species successfully established from seed. Marsh plant establishment from seed presents several problems. The germination of most seeds is highly variable, and, in order to ensure moderate success, seeds must be correctly pretreated. Seeds are also vulnerable to being dislodged and swept out of the sediment by tidal action or heavy rainfall. Under most natural conditions only a very small percentage of seeds can be expected to produce seedlings. Since seedlings are delicate and therefore extremely vulnerable to physically and biologically mediated damage, losses at this stage of development may be as prohibitive to establishment as poor germination. It is notable that among natural populations of marsh plants, establishment in uncolonized areas usually does not occur by seed.

Although plant populations were comparably established from all vegetative propagules on freshwater sediments, populations were established with much less success from rhizomes than from transplants in the estuarine sediments. Differences in the sensitivity of

Table 2

MEAN BIOMASS OF PLANTS ESTABLISHED ON DREDGED SEDIMENTS

Experiment	Species	Biomass	Sediment Type-Mean Biomass, g m^{-2} (dry wt)* Sand	Clay	Silty Clay
Freshwater marsh	*Cyperus esculentus*	Total	65 a	1587 b	2875 c
		Aboveground	34 a	995 b	2263 c
		Belowground	31 a	592 b	612 b
	Scirpus validus	Total	234 a	1368 b	2324 c
		Aboveground	108 a	881 b	1856 c
		Belowground	126 a	487 b	468 b
Brackish marsh	*Distichlis spicata*	Total	234 a	1047 b	1978 c
		Aboveground	124 a	749 b	1466 c
		Belowground	110 a	298 ab	512 b
	Spartina patens	Total	373 a	283 a	1704 b
		Aboveground	227 a	171 a	1227 b
		Belowground	146 a	112 a	477 b
	Triglochin maritima	Total	151 a	–	194 a
		Aboveground	17 a	–	46 b
		Belowground	134 a	–	148 a
	Scirpus robustus	Total	235 a	–	518 b
		Aboveground	53 a	–	185 b
		Belowground	182 a	–	333 b
Salt marsh	*Spartina alterniflora*	Total	255 a	1904 b	4670 c
		Aboveground	112 a	1131 b	3056 c
		Belowground	143 a	773 b	1614 c
	Spartina foliosa	Total	145 a	195 a	743 b
		Aboveground	36 a	83 a	390 b
		Belowground	109 a	112 a	353 b

Note: Dash indicates that efforts to establish plants were unsuccessful.

* Means are based on two replications. When followed by different letters, values within a biomass category are significantly different at $P < 0.05$. Significance was determined using Duncan's multiple comparison test.

different propagules to salinity may have affected establishment of the brackish marsh species in this investigation. Compared with the growth of transplants, growth of plants established from other vegetative propagules was much less. This lesser growth was probably induced by the imposition of a limitation on the duration of the investigation. Irrespective of propagative mode, successfully established plant populations can be expected to achieve maximum density, dictated by characteristics of the planting site, within a few years following planting.

Coarse-grained sediments are characteristically poor in nutrients. In this investigation it was concluded that the growth of all species on sand was nutrient limited. Where rapid development of vegetative cover on coarse-grained sediments is desirable, limited application of fertilizer is recommended. However, it must be cautioned that brittle growth induced by high nitrogen levels, coupled with proportionately reduced root growth, would increase the likelihood of severe plant damage from wave action.

Plant growth on fine-grained dredged sediments, where not inhibited by high salinity in this investigation, was comparable to or exceeded most published estimates of plant production in natural marshes. Fertilization of the fine-grained sediments used in this investigation would have served no practical purpose, since existing nutrients would have become limiting only at a much higher rate of production. The characteristically high productivity of marsh vegetation is maintained in part by the continual replenishment of nutrients in the form of nutrient-rich sediments deposited on the marsh. These sediments are not unlike fine-grained dredged sediments, which should, in most cases, contain adequate concentrations of nutrients to support plant growth. Because of this, it is recommended that fine-grained dredged sediments not be fertilized in marsh-creation projects.

The influence of high salinity on the establishment and growth of marsh plants on dredged sediments has not been investigated. However, based on the results of this investigation, it is possible that the salinity of many

estuarine dredged sediments may impede or at least inhibit the establishment of vegetation. Due to salt intrusion in estuarine systems, the salinity of water overlying the sediments may approach that of seawater (35 ppt). As this water is intermixed with sediments during dredging, it may impart higher concentrations of salts to the sediment solution. Since most dredged sediment substrates initially contain between 80 and 90 percent water by weight, even moderate drying can be expected to significantly increase the free-water salinity.

By artificially maintaining a water table and simulating tidal inundation of the sediments in this investigation, it was possible to prevent the increased concentration of salts associated with reduction in water content. However, vegetatively induced accumulations of salts in the fine-grained sediments were noted and discussed herein. Since the development of organic structure in a fine-grained sediment would eventually promote leaching, plants might be selected on the basis of their ability to rapidly accrue belowground mass in sites where salinization processes would be expected to adversely affect marsh-creation efforts. Additionally, the burrowing activities of invertebrate animals can be expected to promote improvements in drainage.

The study, DMRP Work Unit 4B06, was conducted by Drs. J. W. Barko and C. R. Lee, Ms. M. C. Landin, and Messrs. R. M. Smart, T. C. Sturgis, and R. N. Gordon of the Ecosystem Research and Simulation Division, EEL, WES. The report of the study, Technical Report D-77-2, is available on request.

UPCOMING EVENTS

The Twenty-Fifth Annual American Society of Civil Engineers Specialty Conference will be held 10-12 August 1977 at Texas A&M University. The theme for this year's conference is *Hydraulics of the Coastal Zone*. The conference is cosponsored by the Hydraulics Committee of ASCE and Texas A&M Civil Engineering Department. Requests for information should be directed to Dr. Robert E. Schiller, Jr. (Civil Engineering Department), Conference Chairman, Texas A&M University, College Station, TX 77843.

Second International Symposium on Dredging Technology will be held 2-4 November 1977 at Texas A&M University. The Symposium is cosponsored by the British Hydromechanics Research Association and the Center for Dredging Studies. The Symposium is of major interest to those concerned with the scientific and technical aspects of modern dredging. Further information may be obtained from Mr. H. S. Stephens, BHRA Fluid Engineering, Cranfield, Bedford, MK43 OAJ, England, or Dr. John B. Herbich at Texas A&M University.

Fifth Dredging Shortcourse will be held 7-11 November 1977 at Texas A&M University. The Shortcourse will cover the following topics: dredging equipment, sediment transport in pipes, geotechnical mechanics, similitude relationships, and model testing, instrumentation, environmental effects of dredging, environmental impact statements, etc. For further information write Dr. John B. Herbich at Texas A&M University, Civil Engineering Department.

NEW LITERATURE

Johnson, J. J., "Feasibility of Using Historic Disposal Areas, Upper Mississippi River, to Evaluate Effects of Dredged Material Disposal on Community Structure of Benthic Organisms," Miscellaneous Paper Y-76-3, July 1976, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Environmental studies addressing the effects of dredged material disposal on the community structure of benthic organisms in freshwater systems are extremely scarce. Most studies of this general nature have been conducted in marine environments and have emphasized short-term effects, rather than long-term effects. The community structure of benthic organisms occurring in four historic disposal areas (1969, 1972, 1973, and 1974), Pool 25, Mississippi River, was investigated in June 1974 to determine if these areas, with known disposal histories, could be evaluated in terms of effects related to the disposal of dredged material. Concurrently, unaffected control areas were also studied to differentiate between effects related to disposal activities and those associated with natural changes. The community structure of benthic organisms was described in terms of numerical abundance, biomass, species diversity, and evenness indices. Substrate types and water depths were also described for each sampling area.

NOTE: The DMRP regrets it cannot be a distributing agent for the new items of literature listed in this bulletin. All items presented are available at the time of listing from the publishing or issuing agency and requests for copies should be addressed to them. In many instances, only limited copies are available and the use of Interlibrary Loan or related services is encouraged.

Bonner, W. P., and Bustamante, R. B., "Behavior of Mercury in Suspended Solids and Bottom Sediments," Report OWRT-A-027-TENN(1), Jul 1976, Water Resources Research Center, University of Tennessee, Knoxville, Tennessee.

Laboratory studies were conducted to show several relationships between selected components of an aquatic environment containing mercury. The data show that mercury as mercuric chloride, mercuric sulfide, phenyl mercuric acetate, and metallic mercury becomes associated with sediments very rapidly and with time natural mechanisms in the sediments tend to stabilize or bind the mercury and make it less available to the aquatic environment. Organic components of the water-sediment system play an important role in binding mercuric mercury. Experimental fish show an increase in both the rate of uptake and elimination with increasing temperature between 9 and 30 C. Inorganic forms of selenium and mercury are antagonistic toward the toxicity of each other. Collectively, temperature and the presence of naturally occurring organic materials and antagonistic agents could significantly reduce the possibility of mercury accumulation in a food chain leading to man.

This bulletin is published in accordance with AR 310-2. It has been prepared and distributed as one of the information dissemination functions of the Environmental Effects Laboratory of the Waterways Experiment Station. It is principally intended to be a *forum* whereby information pertaining to and resulting from the Corps of Engineers' nationwide Dredged Material Research Program (DMRP) can be rapidly and widely disseminated to Corps District and Division offices as well as other Federal agencies, State agencies, universities, research institutes, corporations, and individuals. Contributions of notes, news, reviews, or any other types of information are solicited from all sources and will be considered for publication as long as they are relevant to the theme of the DMRP, i.e., to provide—through research—definitive information on the environmental impact of dredging and dredged material disposal operations and to develop technically satisfactory, environmentally compatible, and economically feasible dredging and disposal alternatives, including consideration of dredged material as a manageable resource. This bulletin will be issued on an irregular basis as dictated by the quantity and importance of information to be disseminated. Communications are welcomed and should be addressed to the Environmental Effects Laboratory, ATTN: R. T. Saucier, U. S. Army Engineer Waterways Experiment Station, P. O. Box 631, Vicksburg, Miss. 39180, or call AC 601, 636-3111, Ext. 3233.

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

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U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION
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